2/PRTS
10/552594
JC09 Rec'd PCT/PTO 07 OCT 2005
Pc 10665

Hydraulic Vehicle Brake System

The present invention relates to a hydraulic vehicle brake system, including a hydraulic brake pressure generator which essentially consists of a master brake cylinder and a hydraulic booster connected upstream thereof, the pressure of which can be applied to wheel brakes of the vehicle, which hydraulic brake pressure generator is connected by way of a conduit to a pressure fluid supply reservoir, which hydraulic brake pressure generator includes a vacuum chamber arranged essentially coaxially to the master brake cylinder as well as a booster piston arranged therein, which hydraulic brake pressure generator is effectively connected to a master brake cylinder piston in the force-output direction by way of an actuating element and, for the purpose of brake force boosting, can be acted upon by a hydraulic pressure of an electronically actuatable independent pressure source which is connected to the hydraulic booster by way of a conduit in which a second analog or analogized valve is arranged.

An appropriate vacuum supply for brake force boosting has become rare in new engine technology such as Diesel engines, direct-injection gasoline engines, or electric drives. This fact necessitates brake systems with active hydraulic brake force assistance or with an additional vacuum pump for the operation of a vacuum brake booster.

Further, the relatively large structural dimensions of the vacuum brake booster are principally disadvantageous. Problems are also encountered with respect to packaging because the installation position is only difficult to vary.

Therefore, there is a demand in simple brake systems with active hydraulic brake force assistance or with hydraulic brake boosters, respectively.

Systems with active hydraulic brake force assistance assist the driver in the brake pedal actuation by means of a controllable hydraulic pump (OHB systems), e.g. the ABS return pump. These systems increase the point of maximum boosting of a vacuum brake booster without substituting it. It is thus possible to compensate an inappropriate vacuum supply or dimensioning of the vacuum brake booster.

However, systems of this type can cause shortcomings in the field of comfort. In some situations a pedal feeling will occur which is different from 'accustomed' vacuum brake booster assistance in a negative way.

On the other hand, prior-art hydraulic brake boosters are complicated and costly due to high structural efforts. They necessitate additional components to be able to build up pressure actively. This applies especially to brake-by-wire systems such as electrohydraulic brake systems (EHB).

An object of the invention is to provide a hydraulic vehicle brake system with a technically straightforward, uncoupled hydraulic brake pressure generator. Preferably, said brake

system should allow being integrated into an existing hydraulic system by entailing little additional effort.

According to the invention, this object is achieved by the features of the independent patent claims. Preferred embodiments are indicated in the sub claims.

The basis of the invention is a hydraulic vehicle brake system with a simple hydraulic booster that is known from German patent application with the serial number 10244375.0, whose contents is part of this application. The brake system includes a brake pressure generator which is operable by a brake actuating device, in particular a brake pedal, and which is connectable to a wheel brake of the vehicle by way of a hydraulic conduit, and it is provided that the brake pressure generator is basically composed of a master brake cylinder and a hydraulic booster connected upstream thereof, which accommodates a boosting chamber arranged essentially coaxially to the master brake cylinder and a booster piston arranged therein which, in the force-output direction, is effectively connected to a master brake cylinder piston by way of an actuating element and which, for the purpose of brake force boosting can be acted upon by a hydraulic pressure of an independent pressure source which is connected to the hydraulic booster by way of a conduit in which an analog or analogized control valve is arranged. In this system the brake pressure generator is connected to a pressure fluid supply reservoir by way of a conduit in which an additional analog or analogized control valve is arranged.

It is a shortcoming of the prior art system that the increasing demand in comfort and some additional functions,

such as regenerative braking in hybrid or electric drives, can only be fulfilled by a brake system (brake-by-wire system) that is uncoupled from the pedal.

According to the invention, this object is achieved in a hydraulic vehicle brake system according to the preamble of patent claim 1 in that the pressure fluid supply reservoir is connectable to the electronically actuatable independent pressure source by way of a conduit in which a first analog or analogized valve is arranged, that the vehicle brake system includes a simulator cooperating with the brake actuating device and a device for detecting the deceleration request of the driver, and that the electronically actuatable independent pressure source is actuatable according to the detected deceleration request of the driver or according to an electronic brake control system.

The invention renders it possible to actively develop brake pressure by entailing low structural effort and, hence, low costs, and to introduce the brake pressure according to an uncoupled brake actuating device or a specification from the brake control system as is e.g. the case in an automatic brake intervention by a collision avoidance control or in an ESP brake intervention (brake-by-wire system). The advantages of a brake-by-wire system can therefore be utilized.

Further advantages are achieved by the closed design of the system. No problem is encountered in the volume balance of the pressure fluid, which is in contrast to other brake systems where the volume for brake pressure generation is principally provided by a high-pressure accumulator and is discharged into the supply reservoir.

According to the invention, the brake actuating device is uncoupled from the brake pressure generator and, thus, from the hydraulic connection to a wheel brake of the vehicle in the 'normal case', that means without system errors. Only in a case of fault, particularly upon failure or malfunction of the electronically actuatable independent pressure source, will the brake actuating device be coupled hydraulically to the wheel brakes by way of the hydraulic brake pressure generator (hydraulic through grip).

Analog or analogized valves are employed according to the invention which, by means of an electric or electronic independent actuation, preferably are able to adopt all positions or at least a great number of positions between OPEN and CLOSED so that the brake pressure for controlled or comfort braking operations can be increased or reduced in a preferably infinitely variable, at least almost infinitely variable, fashion. It is preferred to adjust the analog or analogized valve with a current value.

The master brake cylinder according to the invention preferably has a dual-circuit design and, in particular, is configured as a tandem master cylinder (TMC), while the pressure fluid supply reservoir is of an unpressurized design.

The independent pressure source according to the invention includes a motor-and-pump assembly and a hydraulic high-pressure accumulator. Preferably, a hydraulic return pump already provided in a brake system or a motor-and-pump assembly for return delivery is used.

According to the invention, an electronic controlling and regulating unit is provided which is used to regulate or control the analog or analogized valves for the purpose of applying a defined hydraulic pressure to the booster piston of the hydraulic booster, and a determining unit is associated with the electronic controlling and regulating unit or integrated into it for the purpose of determining the driver's braking request.

It is arranged for by the invention that the master brake cylinder is connected to the wheel brakes of the vehicle by way of a brake conduit into which a separating valve is inserted, and by way of subsequent brake conduit parts in which each one inlet valve is arranged.

According to the invention, the wheel brakes of the vehicle are connected to the master brake cylinder by way of a return conduit in which outlet valves, a low-pressure accumulator and a change-over valve are arranged.

The pump is connected to the return conduit on the inlet side according to the invention, while on the outlet side it is connectable to the wheel brakes of the vehicle or to the high-pressure accumulator through a branching, and a non-return valve and a damping chamber are arranged between the pressure side of the pump and the branching.

It is provided by the invention that from the branching the pump is connected to the high-pressure accumulator by way of a conduit in which a first actuatable valve is arranged, while the pump is connected from the branching to the brake conduit

parts by way of a conduit in which an additional actuatable valve is arranged.

It is provided by the invention that the electronic controlling and regulating unit is used to regulate or control the actuatable valves for the purpose of regulating a hydraulic brake pressure or building up pressure in the high-pressure accumulator.

It is arranged for in the invention that the simulator includes at least one hydraulic chamber which is connected to the conduit between the hydraulic booster by way of a conduit in which an additional valve, preferably a NO valve (open in the de-energized condition) is arranged.

According to the invention, a separate charging circuit is provided for the high-pressure accumulator, which includes a three-circuit hydraulic pump, in particular, and a circuit is used to charge the accumulator. The pump or the charging circuit of the pump is then connected to a supply reservoir for the pressure fluid by way of a separate conduit, and valve 1 can be omitted. The result is that the charging of the high-pressure accumulator is advantageously independent of control activities.

It is arranged for by the invention that the first and the second analog or analogized valve are NC valves (normally closed valves).

According to the invention, the hydraulic brake pressure generator, that means basically the booster and the tandem

master cylinder, is integrated into a hydraulic unit, meaning the hydraulic block (HCU) of the brake system.

The invention will be described in detail in the following by way of the accompanying drawings (Figures 1 and 2).

In the drawings:

Figure 1 shows a brake pressure generator for the brake system of the invention.

Figure 2 shows a brake system according to the invention.

According to Figure 1, the brake pressure generator includes a hydraulic booster 7 which is designed as an extension of the actuating unit (TMC) 11 with reservoir 13. The booster piston 41 is guided in a booster housing, and a push rod 42 of the booster piston 41 is supported in the piston 51 of the push rod circuit of the TMC 11 or is guided through a corresponding plate-type extension 52 of the diameter in the TMC bore 53. The booster housing 40 can be flanged as a separate component to the TMC 11. However, in a particularly favorable fashion, the booster (7) and the TMC (11) are integrated as a unit into the prior art hydraulic unit, the known hydraulic block (HCU) (see Figure 2). In a favorable manner the reservoir 13 can then be arranged separately at an appropriate position in the engine compartment (see reservoir 13a in Figure 2). This gives the liberty to arrange the HCU with the integrated booster-TMC unit in such a manner that optimal packaging, i.e. an optimal utilization of space, can be achieved.

After the assembly of the booster piston 41 with push rod 42, or after the assembly of the TMC pistons 51, 54 and the booster piston 41, the booster housing 40 is appropriately closed. Behind the booster piston 41 being in its inactive position, there is a hydraulic port 43 accommodating a control conduit 50 and opening into a chamber, i.e. chamber 47 behind the booster piston 41. A bleeding bore 44 (or intended for ventilation) is provided on the side of the push rod 42. The displacement travel of the booster piston 41 corresponds to the added stroke of both circuits (floating circuit SK and push rod circuit DK) of the TMC 11.

The ratio of surfaces of booster piston 41 and TMC surface in conjunction with the pressure provided by a high-pressure source results in the TMC pressure to be achieved with the aid of boosting (corresponds to the point of maximum boosting of the booster).

$(A_{booster}/A_{TMC}) * P\ HDQ = P_{TMC,\ boosted})$

wherein:

$A_{booster}$:	surface of the booster piston
A_{TMC}:	surface of the TMC piston
P_{HDQ}:	pressure of the high-pressure source
$P_{TMC,\ boosted}$:	TMC pressure which can be reached with boosting

Thus, it is arranged for to vary the pressure demanded by a control or regulation by means of the surface ratios or the pressure of the high-pressure source.

Preferably, a hydraulic high-pressure accumulator is used as a high-pressure source. For example, a high-pressure gas accumulator having a volume of 200 to 300 cm^3 and a gas filling pressure of approximately 10 to 15 bar at 20 °C is employed. The high-pressure accumulator is preferably fed by a hydraulic pump with pressurized pressure fluid, i.e. it is 'charged'. Charging the accumulator after a braking operation is e.g. done when a hydraulic pressure in the accumulator of lower than 40 to 50 bar is reached, what corresponds to a brake pressure (maximum boosting pressure) of 80 to 90 bar. Until a top threshold value for the hydraulic pressure in the accumulator of 50 to 70 bar is reached, corresponding to a maximally attainable boosting pressure of 80 to 110 bar, a charging time by the pump of roughly 2 to 3.5 sec is required when brake application was performed until the point of maximum boosting and a fastest possible filling of the accumulator shall be ensured by a maximum pump operation. With less strong brake applications and a correspondingly lower volume flow out of the high-pressure accumulator 4, less significant pump actuations, in particular actuations of the pump or of the associated motor, will be performed for a short period, e.g. in the range of milliseconds. Admittedly, this procedure extends the charging time of the high-pressure accumulator, yet it is suitable under comfort aspects. Thus, the pump noise can hardly be noticed by the driver due to a favorable actuation of the pump or the motor for some milliseconds. Hence follows that his design will ensure an appropriate supply to the hydraulic brake booster 7 in conformity with the up-to-date brake systems with a vacuum brake booster.

A preferred embodiment for the entire hydraulic system with the actuating unit 11 and a connected brake circuit (of two brake circuits in total) which acts upon two wheel brakes 30, 31 is illustrated in Figure 2. The second brake circuit for the other two wheel brakes is identical with the illustrated brake circuit in terms of design and function and, therefore, need not be described in detail.

The brake circuits are acted upon by the master cylinder (TMC) 11 according to Figure 2. The pressure requested from the respective control or regulation of an electronic unit 28 in conjunction with a driver braking request determination unit 64 is produced by way of the hydraulic booster 7 and the master cylinder 11.

The wheel brakes 30, 31 are supplied with pressure by way of normally open (NO) valves 15.1 and 15.2 directly out of the TMC 11 through a conduit 14, a NO separating valve 9 and subsequent conduits 14.1 and 14.2, with the TMC 11 being actuated by way of the hydraulic booster 7. The hydraulic booster 7 can be acted upon by hydraulic pressure of a high-pressure accumulator 4 through a conduit 50 into which a valve 5 is inserted. The high-pressure accumulator 4 is supplied with hydraulic pressure by a motor-and-pump unit 19, 20. Between the valve 5 and the subsequent control conduit 50 to the booster 7, a branching is provided leading through a conduit 62 to a preferably one-circuit pedal simulator or pedal travel simulator 61. A valve 63, preferably a NO valve, is inserted into the conduit 62. Valve 63 is operated, i.e. closed, in all booster control operations. This valve remains open and permits a direct pressure buildup in the booster only in the case of a system malfunction.

An opening 45 to the atmosphere is provided on the rear side of the simulator 61. The push rod 46 of the brake pedal 26 enters into the simulator 61 upon brake application. The push rod movement is sensed by means of a travel sensor 60 and used as a command variable for determining the driver's request, which is then realized correspondingly in the booster 7. It is advantageous in this system that the push rod 46 of the brake pedal 26 is not moving in brake fluid but in air, what makes sophisticated sealing unnecessary.

Brake pressure in the wheel brake is discharged by way of a return conduit 17 and normally closed (NC) valves 16.1 and 16.2 into the low-pressure accumulator 18 which is connected, by way of a NC change-over valve 8, to the TMC 11 through conduit 14.

A high-pressure accumulator 4 is typically charged by opening a valve 2. When the pressure in the high-pressure accumulator drops below a predetermined nominal value, in particular below 50 bar to 70 bar, brake fluid is aspirated from the TMC 11 through the open change-over valve 8 and by means of the pump 19 operated by the motor 20. The brake fluid is pumped into the high-pressure accumulator 4 by way of a non-return valve 23 connected to the pressure side 21 of the pump 19, a damping chamber 57, through a conduit branching 22 and a conduit 24 into which the valve 2 and a pressure sensor 3 are inserted. The motor 20 is then actuated until a predetermined nominal pressure is achieved. The pressure is measured by a pressure receiver (pressure sensor 3). When the high-pressure accumulator 4 is filled (accumulator charging), the valve 5 arranged in a conduit 50 between high-pressure accumulator 4

and booster 7 is closed. The pressure side of the pump is connected to the wheel brakes 30, 31 also by way of branching 22 and a connected conduit 25 in which a valve 1 is inserted. Preferably, the valve 1 is closed in the de-energized condition (NC valve) and valve 2 is open in the de-energized condition (NO valve). Thus, these valves are not energized during the charging of the accumulator, and favorably only the change-over valve 9 must then be energized for the filling operation. It is likewise possible to design valve 1 as a NO valve and valve 2 as a NC valve, but it is then necessary to invert the switching conditions correspondingly.

It is alternatively envisaged to provide a separate charging circuit for the high-pressure accumulator 4. A three-circuit hydraulic pump is e.g. used, and one circuit of the pump serves to charge the accumulator. The pump or the charging circuit of the pump is then connected by way of a separate conduit to the reservoir 13a for the pressure fluid. Valve 1 may be omitted.

At high control frequencies with a low volume requirement in the wheel brake, it is possible to use the total of the discharged volume or parts thereof for charging the high-pressure accumulator 4.

The charging operation of the high-pressure accumulator 4 is immediately stopped as soon as a braking maneuver of the driver is recognized. It is preferred to carry out charging operations in acceleration periods (without control). The detection of a braking maneuver is done by way of the pedal travel sensor 60 or any other sensor sensing the braking

request of the driver as well as the braking request determining unit 64.

When a braking request is determined, the valve 5 of analog operation, preferably a NC valve, is correspondingly opened in dependence on the displacement travel of the push rod 46 of the brake pedal 24 and/or the actuating speed, and valve 63 is closed so that brake fluid can flow from the charged high-pressure accumulator 4 into the chamber 47 disposed behind the booster piston. The buildup of the pressure in the booster 7 is monitored by a pressure sensor 10 by way of the pressure developing in the TMC. This means a defined travel is associated with a defined pressure in the TMC and adjusted.

When the driver releases the brake pedal, i.e. when the travel decreases again, valve 5 will be closed and a valve 6 of likewise analog operation inserted in a conduit 12.1 and a subsequent conduit 12 between the high-pressure accumulator 4 and the reservoir 13a is opened in analog manner corresponding to the cancelled driver request. The brake fluid can thus flow back again into the supply reservoir 13a via the conduit 12.1 and the subsequent conduit 12. A conduit 12.2 is also provided between the TMC 11 and the supply reservoir 13a, connecting to conduit 12, for the purpose of pressure fluid flowing back into the reservoir 13a.

Valve 6 can also shut off the remaining system. Designing the valve 6 as an analogized NC valve reduces the additional valve structure to a valve, compared with systems having a simple hydraulic booster, like the system described in DE 102 44 375.

The combination of the hydraulic booster and the auxiliary pressure source with high-pressure accumulator 4 according to the invention can be designed in such a fashion that the total brake pressure required is generated by the booster. However, this fact will increase the necessary accumulator pressure in the high-pressure accumulator 4.

In another embodiment, only a reduced maximum brake pressure of the booster (maximum boosting pressure) is made available (similar to a vacuum brake booster). This reduced maximum boosting pressure will then cover already a large range of all braking operations, e.g. all 'normal braking operations' in a range of a maximum of up to 60 to 100 bar of resulting brake pressure. The braking operations which require a brake pressure (roughly 60-100 bar) that lies in a range in excess of this point of maximum boosting are then realized by an additional pressure buildup by means of the hydraulic pump 19, as is the case in an optimized hydraulic brake with brake force boosting by way of a hydraulic pump (OHB-V). This can cause a 'pull-away' of the TMC piston. Then pressure fluid is conducted through conduit 50 and valve 5 into the booster chamber 47 and thus the piston 41 is positioned accordingly. This embodiment is preferred because the mounting space is further reduced this way. Another advantage can be seen in that in this case only relatively small volume flows of brake fluid must be moved, whereby the system's dynamics is increased. This condition will also reduce the charging times of the high-pressure accumulator 4. Due to the additional hydraulic boosting by means of pump 19, it is also possible to rate the volume of the high-pressure accumulator 4 to a lower repetition frequency of braking operations. This means, the number of possible braking operations without intermediate

charging of the high-pressure accumulator can be reduced to e.g. two times 60 bar to 90 bar, preferably roughly 80 bar, of TMC pressure. A corresponding brake pressure can be produced by pump 19 in the rare cases of an exceeding pressure requirement.

The simulator 61 represents a cylindrical component, similar to a TMC, which is equipped with a packing preferably in the secondary circuit only. The secondary circuit is filled with brake fluid and preferably cushioned. The primary circuit disposed in front of the secondary circuit is preferably not provided with a packing, but is preferably also cushioned. The pedal feeling is simulated with this cushioning arrangement, and is thus freely adjustable. When this circuit is also furnished with a packing, the interposed air cushion can also be used as a spring.

In case the total system fails or booster-relevant parts of the system fail, the simulator 61 serves as a fallback mode and is able to pressurize the booster 7. The reservoir 13a is separated from the system by way of valve 6, preferably a NC valve, and the simulator 61, by way of the additional valve 63, preferably a NO valve, has the possibility of taking care of the energy supply to the booster 7. As the simulator 61 will thus act on the booster only, it is hence only necessary that the simulator 61 has a one-circuit design. The dimensioning of the simulator 61 as well as the cushioning arrangement determine the actuating forces and the possible residual braking effect when the simulator volume is exhausted, and they can be adapted to comply with the respective requirements.

The simple hydraulic booster 7 and the TMC 11 are herein accommodated as a highly integrated unit in the hydraulic block (HCU, dotted line 67), that means they are designed as one component. The necessary supply reservoir 13a is associated with the simulator 61; preferably it is arranged directly on the simulator or at least adjacent to it. Two 'supply conduits' (12, 12.2) lead from the supply reservoir 13a to the integrated TMC 11. Pressure reduction of the booster 7 takes place through valve 6 by way of the additional conduit 12.1. The supply reservoir 13a is likewise connected to the secondary circuit of the simulator 61. By way of circuit 62, the secondary circuit has a connection (fallback conduit) to the control conduit 50. Valve 63 is arranged in this fallback conduit.

This construction renders an emergency actuation of the TMC 11 possible, should the booster 7 fail. This is due because the driver is able to actuate the piston 41 also directly, that means in a hydraulic-mechanical way in case of a malfunction or failure of the hydraulic pressure. The actuating element (push rod 46) causes movement of a simulator piston 66 in the simulator 61, and hydraulic pressure is transmitted into chamber 47 and, thus, onto the booster piston 41 by way of the preferably NO valve 63 in the connecting conduit 62 or fallback conduit between simulator 61 and TMC 11.

The described system is especially favorably applicable for electronic brake control systems, such as ABS (anti-lock system), EDS (electronic differential lock), traction slip control), ESP (Electronic Stability Program), HDC (Hill Descent Control), collision avoidance control (ACC - Adaptive Cruise Control), HSA or regenerative brake, because an

introduction of brake pressure independent of the driver is possible and an automatic pressure compensation of the circuits is executed by the TMC 11.